Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at http://about.jstor.org/participate-jstor/individuals/early-journal-content.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

AN ELECTRICAL CONSTANT TEMPERATURE APPARATUS

CONTRIBUTIONS FROM THE HULL BOTANICAL LABORATORY 151

W. J. G. LAND

(WITH FOUR FIGURES)

The temperature of incubators heated with gas taken directly from the mains is very irregular when an attempt is made to control the flow with mercury-actuated thermostats commonly used. Most mercurial thermostats will compensate for slight variations from the mean gas pressure, but not for large ones. The rise in temperature in the water-jacketed incubators used in the Hull Botanical Laboratory for paraffin infiltration was so sudden and so high that delicate plant tissues were often much distorted.

Electrically controlled heaters have been placed on the market recently by makers of repute, but the price of the apparatus ($50 and $100) is unreasonably out of proportion to the cost of material and labor.

In order to test the effect of definite temperatures on plant tissues for a longer time than is usually employed in imbedding, and having a direct current of 110 volts constantly on in the laboratory, the problem of devising a simple and efficient electrically controlled heater was first attacked about four years ago. The conditions of the problem were that the apparatus must maintain a definite temperature constant within very narrow limits for weeks at a time, must be easily adjustable to temperatures ranging from 40° C. to 80° C. with certainty, must be absolutely automatic in action, must be readily attachable to the usual type of ovens, must require practically no attention to keep in order, must be simple and inexpensive to construct, must use a minimum quantity of electricity, and must not be easily put out of adjustment by inexperienced or meddlesome persons.

For over two years the apparatus here described has replaced the gas heaters in this laboratory, with satisfactory results. The risk of fire, always great when gas is used, has been eliminated.

So many requests for information concerning the apparatus have been received that it has become impossible to give individual replies.

The apparatus consists of a metallic thermostat (fig. 1) placed on a shelf in the oven, a water-jacketed heating coil (fig. 2) fastened to the bottom of the oven in such a way that the water jacket of the coil forms a continuous system with that of the oven, and an automatic switch (fig. 3) placed wherever convenient.

The thermostat (fig. 1, *n*) is a thin strip of iron about 1 mm. thick and 2 cm. wide, firmly riveted to a strip of zinc the same width and from 1.5 mm. to 3 mm. thick. One end is fastened to a brass post set rigidly on the slate base, and the other end swings free. The free end of the metal tongue has a contact point of platinum fastened to the zinc side near the end. The adjustment for temperature is made with a platinum-tipped screw (*d*) set so that its point can always be brought in contact with the platinum disk on the metal tongue. The metal tongue and the adjusting screw are connected respectively with the binding posts (*b*, *b'*), as shown in the diagram.

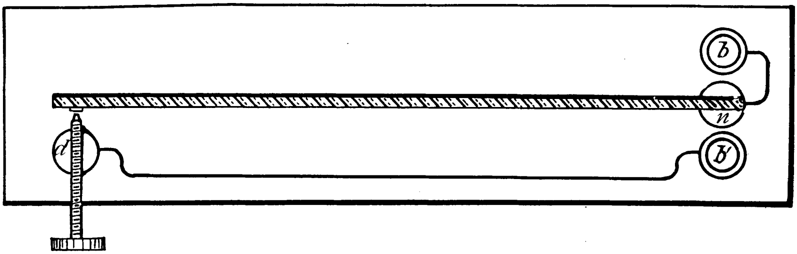

FIG. 1.—Diagram of thermostat and connections; *n*, thermostat of zinc and iron; *d*, screw for adjusting temperature; *b*, *b'*, binding posts to connect with *t*, *t'* of the switchboard.

The base of the thermostat should be made long enough to fit easily in the oven, the ends resting on ledges provided for the upper shelf. The sensitiveness of the thermostat depends, of course, on the length of the metal tongue. If extreme sensitiveness is required, it may be made nearly twice the length of the base and bent to a U, or it may be much longer and coiled. In practice 20 cm. has been found satisfactory. The zinc strip should not be thinner than

1.5 mm., or the thermostat will respond unpleasantly to any tremor of the bath or even in the laboratory building. If desired, brass or aluminium may be substituted for the zinc. The regulating screw should be made long enough to provide for quite a range of temperature. When the thermostat has been adjusted to the required temperature, it will need no further attention, except perhaps to brush the dust from the contact points at very long intervals. To raise the temperature turn the screw to the right, to lower it turn it to the left.

The heater (fig. 2) is a water-jacketed resistance coil of brass tubing and German-silver resistance wire. The tubing need not be thicker than 1 mm. The coil should be proportioned to the size of the oven it is intended to heat. For ovens having internal dimensions of 20×25×26.25 cm., and for temperatures of 30°–80°C., the size given here has been found suitable. Such a coil, however, will heat much larger ovens satisfactorily. The brass tubes should be about 15 cm. long. The resistance coil is four layers of no. 21 German-silver wire, wound on a tube 3 cm. *inside* diameter. The layers of wire are carefully insulated from the tube and from each other with asbestos paper about 0.6 mm. thick. The wire is wound with an engine lathe 24 turns to the inch under considerable tension, and the ends are brought out to binding posts (s, s') in the slate head of the coil. Wound as described, the current at 110 volts measures about 2.2 amperes.

The water jacket is made of 3 concentric brass tubes, the outer one being 6.25 cm. in diameter, the middle one 4.5 cm., and the inner one 3 cm. *outside* diameter, so that the tube of the heating coil will slip over it in close contact. The inner tube is closed at the lower end with a brass disk soldered tightly in place. The upper end remains open, and is fastened to the middle tube by a brass ring. The lower end of the middle tube is in turn fastened in a similar manner to the bottom of the outer tube. A hole is cut in the outer wall of the bottom of the oven, and the outer tube soldered directly to the bottom. If preferred, the outside tube may be threaded and screwed into a flange soldered to the bottom of the oven. If this method is used, a rubber gasket should be placed between the flanges, as shown in fig. 2. This arrangement

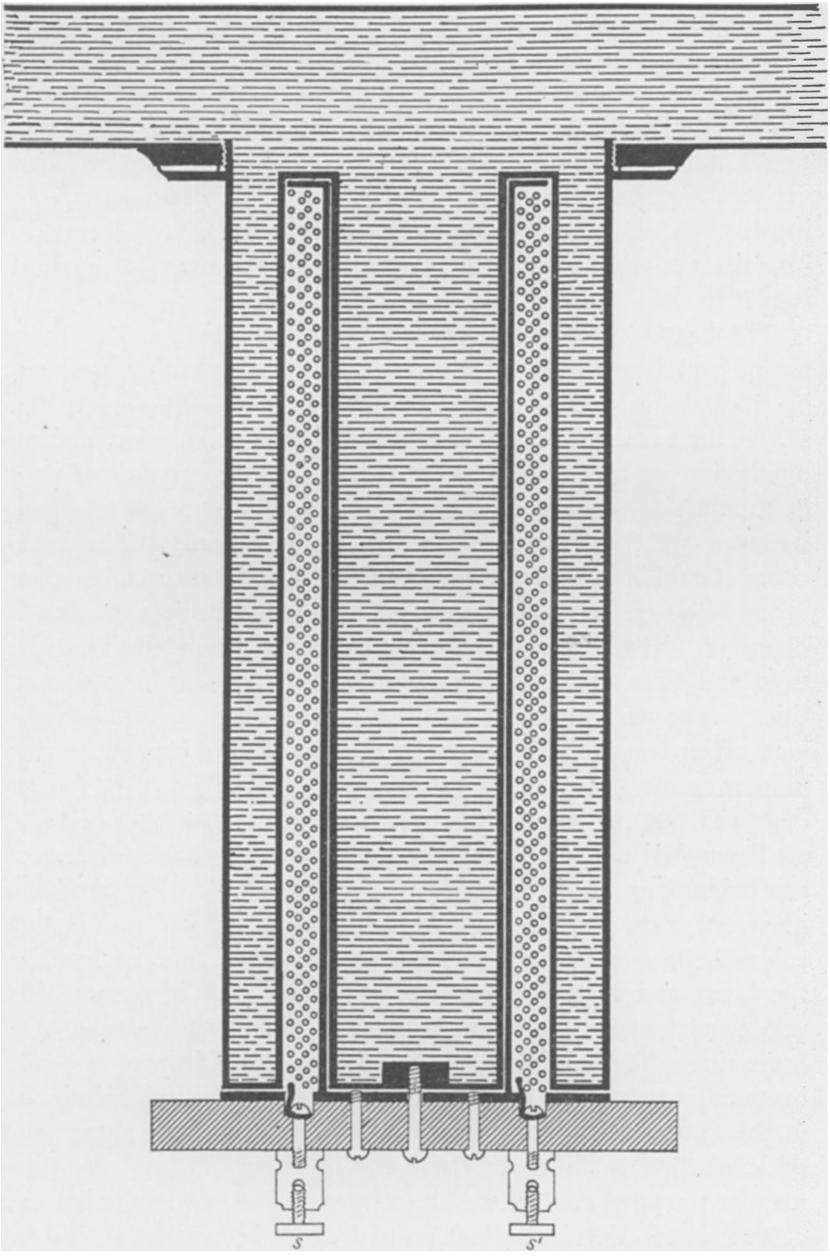

FIG. 2.—Median longitudinal section of heater, showing method of construction of water jacket and resistance coil, and how it is attached to the oven; *s*, *s'*, binding posts to be connected with *h*, *h'* of the switchboard.

adds slightly to the cost, but will permit the sediment which appears in water-jacketed baths to be removed easily. Great care must be taken to have all joints absolutely water tight, since a leak will cause the destruction of the resistance wire in a few hours.

An inspection of the diagram (fig. 2) shows the arrangement is such that the resistance coil is completely surrounded by water except at the lower end, thus insuring rapid conduction of heat. Also the coil can be removed easily if repairs are ever necessary.

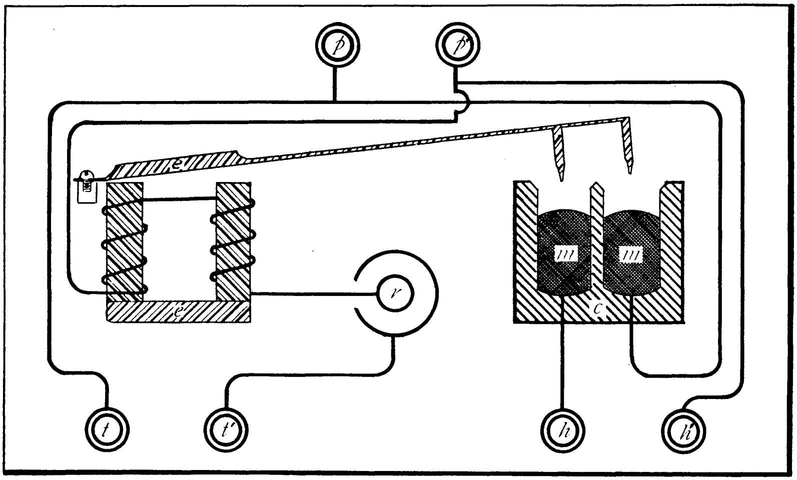

FIG. 3.—Diagram of automatic switch; *p*, *p'*, binding posts to connect with source of electrical supply; *e*, electromagnet; *a*, armature and switch; *r*, gasket for lamp rheostat; *t*, *t'*, binding posts to be connected with thermostat; *c*, container for mercury (*m*, *m*); *h*, *h'*, binding posts to be connected with heating coil.

In two years' use, only one has needed repairs, made necessary by spilling water on the head of the coil when the water jacket was being refilled.

The automatic switch (fig. 3) is a slate base having an electromagnet (*e*), armature (*a*) with switch, and a lamp rheostat (*r*) at one end, and the slate cups (*c*) filled with mercury at the other. A convenient size for the slate base is 20×11.25 cm. The magnets, which can be had very cheaply from electrical supply houses, should have a resistance of about 20 ohms. The armature (*a*) should be fastened by a spring to a pillar rigidly attached to the baseboard, and should extend about 15 cm. to form the arm of the switch. Care must be taken not to have the spring too strong, or the armature will not be pulled down when the current flows through the coils of the magnet. The spring may be much weaker if an 8 or 4 candle power lamp is used instead of a 16 candle power lamp rheostat. One wire connects the post *p* directly to *t;* the other post *p′* is connected through the electromagnet *e* and the lamp rheostat socket *r* with *t′*.

The switch end of the armature should have two iron pins extending downward at a right angle, sharpened, and tinned to insure good contact with the mercury in the cups *c*. In practice it is advisable to drill two holes in the switch arm, tap them, and use iron machine screws for contact points. The screws should be provided with lock-nuts to hold them at the proper length. Switch points gradually wear away, due to the small arc which always occurs when contact with the mercury is broken. The machine screw device permits compensation for this wear. The screws should be sharpened of course, to minimize splashing, and tinned.

The double cup (*c*) for holding the mercury (*m*, *m*) should be made of slate. A convenient sized block is 5×3.75×2.5 cm. The holes for mercury should have a diameter not less than 1.25 cm., preferably 2 cm., and the edges should be chamfered. The mercury oxidizes somewhat rapidly, and in consequence the volume should be rather large. Oxidation of the mercury is the chief defect of the apparatus, but no way has yet been found to prevent it. To compensate for oxidation, a small quantity of mercury must be added occasionally. One wire connects the post *p* with one of the mercury cups, the other cup is connected with *h*. The post *p′* is connected directly to *h′*.

The switch (fig. 3) may be put in any convenient place, preferably out of reach of inquisitive persons. Attach the heating coil (fig. 2) to the oven and place the thermostat (fig. 1) inside the oven on the upper ledges and connect the posts *p*, *p′* of the switch with any convenient lamp socket, fill the cups *c* with mercury, screw a lamp in the socket *r*, connect the posts *t*, *t′* with *b*, *b′* of the thermostat. Connect *h*, *h′* (fig. 3) with *s*, *s′* (fig. 2) of the heating coil. These connections are shown in fig. 4, a photograph of the apparatus.

It is realized that most botanists are not electricians, and therefore the description of the construction and wiring of the instrument is not written for experts.

The action of the apparatus is as follows: When the platinum points of the thermostat are in contact, the current flows through the electromagnet, the armature is drawn down, closing the switch and making a circuit through the heating coil. The circuit will remain closed only so long as the platinum points of the thermostat are in contact. As the temperature of the oven rises, the platinum points are separated, the circuit through the electromagnet is broken, and the switch is opened by the release of the armature.

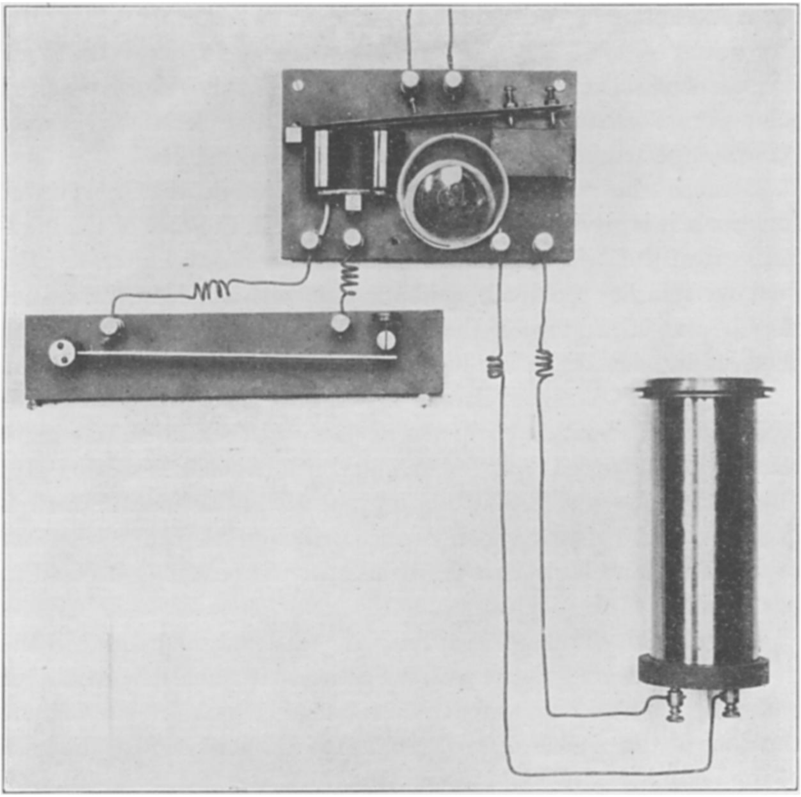

FIG. 4.—Photograph of thermostat, heater, and switch, with connections.

When the temperature of the oven falls below the required point, the thermostat again functions and the switch is instantly closed. This action continues automatically as long as the current is supplied, or until the mercury in the cups is all oxidized. In one instrument it was found that a difference of 0.01° was sufficient to actuate the mechanism. As has been said before, turning the adjusting screw to the right adjusts for higher temperatures, and vice versa. It will be seen that the two circuits are absolutely independent of each other, and that when the oven is at the required temperature both circuits are broken; that the electricity is only on when the temperature is below the required point.

Because the switch closes so sharply when the thermostat functions, it is advisable to drill a small hole in the core of the magnet nearest the switch and insert a rubber plug for a buffer. If the mercury splashes too much, rubber corks, with a hole in the center, may be put in the tops of the cups. The flash which occurs when the switch points leave the mercury is bright, but it does no harm.

It is possible to use an alternating current, but it is very difficult to adjust the armature spring so as to avoid the unpleasant humming. It is planned to try a weighted or balanced armature with alternating currents. A battery may be used to actuate the switch if magnets of lower resistance are used, and the lamp rheostat replaced with a plug; then the alternating current may be used to heat the coil in the oven.

If preferred, the lamp used for a rheostat may be placed in the oven and connected to the socket on the switchboard with a cord and plug. This arrangement is very convenient, for the instant the door of the oven is opened the lamp is lighted. Also the heat of the lamp increases the efficiency of the apparatus.

Anyone at all familiar with tools can construct the apparatus at a cost of about $3.75 for material. Of course he must have access to an engine lathe to wind the coil so that the wires will not touch each other. After the first experimental instrument was found to work satisfactorily, the interest of a very expert mechanician, Mr. A. W. STRICKLER, 1311 E. 57th St., Chicago, Ill., was enlisted. He suggested many improvements, always having in mind increase of efficiency and lowering of cost. It is largely due to his interest in the problem and his skill in construction that the apparatus has proved so efficient in this laboratory. He has recently devised a form of this thermostat which can be used with safety where explosive gases are present. He finds that when made as described here the cost should not exceed $15.00 for the apparatus complete and ready to attach to the incubator.

THE UNIVERSITY OF CHICAGO